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The Ohio Land Allocation Model: Report on Phase II

by

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Mary Karen Wilson and Harvey Curran performed the aerial photo interpretation which will be used to check the accuracy of the LANDSAT data. Mary Karen Wilson took primary responsibility in insuring the accuracy and usefulness of this information and helped to write the portion of the report dealing with this topic. This work was greatly aided by the advice of Gary Schaal of the Ohio Department of Natural Resources who helped secure permission to utilize the Zoom Transfer Scope. In addition to the tasks mentioned above, Harvey Curran researched and wrote Appendix B and designed the concept of the final computer models.

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INTRODUCTION

This document is the second report concerning the Ohio Land Allocation Model. During Phase I, reviews were made of models of land use change and the uses of LANDSAT data for modeling.[1] A standard set of land categories was formulated and an initial set of tax assessment and tax parcel models were derived.

There were several additional tasks carried out in this phase of the study. These include:

1) The formulation of tax assessment models for the agricultural sector;
2) Sampling of parcel size data from three central Ohio counties to establish the feasibility of converting the tax parcel data to land acreage data;
3) Interpretation of aerial photogarphy for Franklin County, Ohio, for use in quantifying the potential errors in LANDSAT data interpretations;
4) The formulation of a standardized data base for use in Phase III - checking the errors in LANDSAT interpretations.

The results of these tasks are summarized in this report. Also included are two appendices. Appendix A discusses the evaluation of the DEMOS model while Appendix B summarizes a study of a step down population projection method for use in Ohio.

[1] Oscar Fisch and Steven I. Gordon, The Ohio Land Allocation Model: Report on Phase I (Columbus, Ohio: Ohio Department of Economic and Community Development, January, 1976).

Finally, the research design for the third and final phase of the land allocation study is given. This section describes how LANDSAT data interpretation accuracy will be tested against the aerial photograph interpretations for Franklin County.

Chapter I

Land Use and Tax Models for the Agricultural Sector

Phase I of the Ohio Land Allocation Model established a number of cross-sectional statistical models of tax assessment and tax parcel changes in the residential, commercial, and industrial land use sectors. Each of these equations utilized the assessed value or number of parcels in each land category as the dependent variables and employment and population as the independent variables. Equations were derived which explained tax base in a static sense (i.e. 1967 residential assessed value for 88 Ohio counties as a function of 1967 employment and population) and in a dynamic sense (change in tax assessed value 1967 to 1972 as a function of change in employment and population during the same period).

Similar models for the agricultural sector did not work as well as those for the other land use sectors. This is because population and employment variables do not incorporate the factors important for agricultural production. For this reason, a data base relating to agricultural production was compiled. Data on cash receipts to Ohio farmers were available from the Ohio Agricultural Research and Development Center.[2] Data on the acreage harvested for each crop type were extracted from Ohio Agricultural Statistics while data on the number of farms, average acreage

[2] Ohio Farm Income, 1967, 1972. Ohio Agricultural Research and Development Center, Wooster, Ohio.

and land in farms by county for 1964-1974 were made available by the Ohio Crop Reporting Service.[3] Table 1 lists the variables which were used in the analysis of the agricultural sector.

Data Analysis

The first step in the project was to analyze the data base using descriptive statistics. The results of this analysis give an overview of the general trends in Ohio's agricultural sector.

Land use in Ohio is diversified. Of the state's 26.2 million acres of land, 11 percent was dedicated to urban and built up areas in 1970; 65.3 percent was in farmland; and 23.7 percent was categorized as other land not in farms.[4] As evidenced from this data, the agricultural sector is clearly a dominant land use within the State of Ohio.

Changes in the state's agriculture indicate that Ohio is following the national trend in that the number of farms and land in farms is decreasing, while average acreage is increasing. Although Ohio is following the national trend, data indicate that the state is not doing so in as radical and rapid a pace as the national average. For example, the average national farm size in 1973 was about 385 acres[5] while Ohio's average farm size for the same year was

[3] Ohio Crop Reporting Service, Ohio Agricultural Statistics, 1967, 1972, Ohio Crop Reporting Service, unpublished data.

[4] Ohio Farm Bureau Federation, "Land Use Task Report," December 4, 1974.

[5] U.S. Department of Agriculture, Statistical Reporting and Economic Research Service, 1973.

Table 1

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

V67001 - Cash Receipts 000's $ Total Livestock 1967

V67002 - Cash Receipts 000's $ Dairy 1967

V67003 - Cash Receipts 000's $ Cattle 1967

V67004 - Cash Receipts 000's $ Hogs 1967

V67005 - Cash Receipts 000's $ Poultry 1967

V67006 - Cash Receipts 000's $ Sheep 1967

V67007 - Cash Receipts 000's $ Other 1967

V67008 - Cash Receipts 000's $ Total Crops 1967

V67009 - Cash Receipts 000's $ Corn 1967

V67010 - Cash Receipts 000's $ Soybean 1967

V67011 - Cash Receipts 000's $ Wheat 1967

V67012 - Cash Receipts 000's $ Oats and Hay 1967

V67013 - Cash Receipts 000's $ Greenhouse 1967

V67014 - Cash Receipts 000's $ Vegs. 1967

V67015 - Cash Receipts 000's $ Other Crops 1967

V67016 - Acres Harvest Corn For Grain 1967

V67017 - Acres Harvest Soybeans for Beans 1967

V67018 - Acres Harvest All Wheat 1967

V67019 - Acres Harvest Oats for Grain 1967

V67020 - Acres Harvest All Hay 1967

V67021 - All Cattle and Calves (Head) 1967

V67022 - All Hogs and Pigs (Head) 1967

V67023 - All Sheep (Head) 1967

V67024 - All Milk Cows (Head) 1967

S67 Acres - Total Acres Harvested 1967

LF 67 - Land in Farms 000's Acres 1967

NF 67 - Number of Farms 1967

Table 1 (cont'd)

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

AA 67 - Average Acreage 1967

INDO 20 - Assessed Value Agricultural Land 1967

INDO 60 - Total Assessed Value Agricultural Land 1967

V72001 - Cach Receipts 000's $ Total Livestock 1972

V72002 - Cash Receipts 000's $ Dairy 1972

V72003 - Cash Receipts 000's $ Cattle 1972

V72004 - Cash Receipts 000's $ Hogs 1972

V72005 - Cash Receipts 000's $Poultry 1972

V72006 - Cash Receipts 000's $ Sheep 1972

V72007 - Cash Receipts 000's $ Other 1972

V72008 - Cash Receipts 000's $ Total Crops 1972

V72009 - Cash Receipts 000's $ Corn 1972

V72010 - Cash Receipts 000's $ Soybean 1972

V72011 - Cash Receipts 000's $ Wheat 1972

V72012 - Cash Receipts 000's $Oats and Hay 1972

V72013 - Cash Receipts 000's $ Greenhouse 1972

V72014 - Cash Receipts 000's $ Vegs. 1972

V72015 - Cash Receipts 000's $ Other Crops 1972

V72016 - Acres Harvest Corn For Grain 1972

V72017 - Acres Harvest Soybeans For Beans 1972

V72018 - Acres Harvest All Wheat 1972

V72019 - Acres Harvest Oats For Grain 1972

V72020 - Acres Harvest All Hay 1972

V72021 - All Cattle and Calves (Head) 1972

V72022 - All Hogs and Pigs (Head) 1972

V72023 - All Sheep 1972 (Head)

V72024 - All Milk Cows 1972 (Head)

Table 1 (cont'd)

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

S72 Acres	- Total Acres Harvested 1972
LF 72	- Land in Farms 000's Acres 1972
NF 72	- Number of Farms 1972
AA 72	- Average Acreage 1972
INDO 25	- Assessed Value Agricultural Land 1972
INDO 65	- Total Assessed Value Agricultural Land 1972
SMSA 67	- Counties in an SMSA, 1967
SMSA 72	- Counties in an SMSA, 1972
AVLIV67	- Mean of Cash Receipts Livestock, 1962-1967, 000's $
AVCRP67	- Mean of Cash Receipts Crops, 1962-1967, 000's $
AVLIV72	- Mean of Cash Receipts Livestock, 1968-1972, 000's $
AVCRP 72	- Mean of Cash Receipts Crops, 1968-1972, 000's $
I021	- Delta ind. Land Assessed Value, 1967-1972
I022	- Delta comm. Land Assessed Value, 1967-1972
I023	- Delta res. Land Assessed Value, 1967-1972
I020	- Delta ag. Land Assessed Value, 1967-1972
I060	- Delta & Total ag. Assessed Value, 1967-1972
CHGCRP	- AVCRP72 minus AVCRP67
CHGLIV	- AVLIV72 minus AVLIV67

almost 149 acres. From 1964-1974 the average acreage on Ohio farms increased by 7.2 acres. The 1969 Census of Agriculture reports that 96.2 percent of all farms in Ohio are less than 499 acres. Small farms, 1 to 99 acres constitute 46.5 percent of this total.[6] This data would seem to indicate that although Ohio is slowly following the national trend, the state remains dominated by relatively small farms and small farmers as opposed to large corporate farming operations that are prevalent in other states. Tables 2 and 3 illustrate these data.

Table 2. Ohio 1964, 1969, 1974

Land in Farms 000's			Average Acres per Farm			Number of Farms 000's		
1964	1969	1974	1964	1969	1974	1964	1969	1974
18,145	17,700	17,400	141.6	148.1	148.8	131	120	117

Source: Ohio Crop Reporting Service

Table 3. United States

Average Acres per Farm		
1964	1969	1974
332	369	385

Source: U.S. Department of Agriculture, Statistical Reporting Service, 1973.

[6] U.S. Department of Commerce, Bureau of the Census, Census of Agriculture, Ohio 1969.

The assessed value of farms in Ohio has increased 23.1 percent from 1964 to 1969. Crops increased 15.4 percent and livestock, poultry, and related products increased 29 percent.[7] Data for 1967, one of the years that will be used in this study, show that livestock products are 57.5 percent of the total while crops constitute 42.5 percent of the total agricultural production in Ohio.[8] In 1972, the other year relevant to this study, livestock products constituted 52.8 percent and crops proved to be 47.2 percent of the total.[9] Table 4 illustrates livestock and major crops by type.

Table 4

	1967	1972
Total Livestock	57.5%	52.8%
Cattle & Calves	14.8%	16.6%
Hogs	14.5%	13.4%
Dairy Products	18.8%	16.9%
Total Crops	42.5%	47.2%
Corn	11.4%	11.9%
Soybeans	12.3%	18.5%
Wheat	5.3%	3.7%

[7] Census of Agriculture, 1969.

[8] Ohio Agricultural Research and Development Center, Ohio Farm Income 1967.

[9] Ohio Agricultural Research and Development Center, Ohio Farm Income 1972.

The next step in the analysis was to delineate the interrelationships among the variables. This was critical in that strong correlations among independent variables in the regression equations (multicollinearity) can yield erroneous results.

Several sets of variables were found to be correlated. First, the analysis showed the relationship among the cash receipts variables and the acres harvested variables to be collinear. This means that in almost all instances the cash receipts from a specific crop and the acres harvested from that same crop will correlate significantly. Table 5 illustrates the correlation coefficients for cash receipts and acres harvested. For example, cash receipts for wheat (V72011) and acres harvested for wheat (V72018) show a correlation coefficient of .90505. Similarly, cash receipts for soybeans (V72010) and acres harvested for soybeans (V72017) correlate at .99385. As a result of this collinearity the regression statements which included both cash receipts and acreage for the same crop would give biased results. It is for this reason that the regressions use only the cash receipts for each crop and livestock variable. The decision to eliminate the acres harvested variables was based on the fact that cash receipts proved to be a stronger explanation of assessed value.

Table 5

RELATIONSHIPS AMONG CASH RECEIPTS AND ACREAGE

HARVESTED VARIABLES

CORRELATION COEFFICIENTS*

	V67018	V67019	V72003	V72016	V72017	V72018
V67009	.90000	.55295				
V67010	.85954	.55772				
V67011	.98199	.63133				
V67012	.65113	.80253				
V67016						
V72009				.89848	.87421	.80287
V72010				.84860	.99385	.84102
V72011				.86372	.93204	.90505
V72016			.67246			
V72021			.82175			

*Underlined coefficients indicate variables which are collinear and should not be used in the same regression equation.

Collinearity was also a factor in determining the relationship among major crop types. This is shown in Table 6. The analysis showed that certain types of crops were intimately related. One explanation for this phenomenon is that certain crops are grown together or alternatively in a rotation. Some crops require the same type of storage soil, or involve similar transportation costs. Soybeans (V72010) and wheat (V72011) correlate significantly. Corn (V72009) is collinear with soybeans (V72010) and with wheat (V72011). Based on the theory of transportation costs one would not expect vegetables (V72014) to correlate highly with wheat or corn. This is, in fact, the case. It may also be posited that vegetables are intensive while wheat and corn are extensive crops, hence they would not be highly related in terms of where they are grown.

Given adjustments in the input data to avoid the use of collinear variables, analysis was carried out using linear regression. The results are summarized in the next section.

Results of Agricultural Sector Models

The goal of the regression analysis was to create predictive models of the tax base related to production in the agricultural sector and the conversion of land to urban uses. In each equation, one of the agricultural tax base variables (e.g. IND060 - total

Table 6

RELATIONSHIPS AMONG MAJOR CROP TYPES

CORRELATION COEFFICIENTS

	V67009	V67011	V72009	V72011
V67010	.89185	.89100	0.89816	0.93534
V67011	.91392	1.00000	0.88707	0.95602
V72010	------	------	.90784	.94601
V72011	------	------	.90587	1.00000

agricultural assessed value, 1967), is the dependent variable and production variables or assessment variables in other categories (residential, commercial, industrial) are the independent or explanatory variables.

Tables 7 to 12 illustrate the results of these analyses. All the tables are similarly organized. Using Table 7 as an example, one can see how to interpret the results. This table represents the models for assessed value of agricultural land as given by the title. Results of two equations are shown in this table - one for 1967 as shown in the left half, and one for 1972 as shown in the right half. On the left margin are the names of all the independent variables for the 1967 equation. The first numbers following this are the B coefficients, the numbers by which one multiplies to arrive at the predicted value for the dependent variable. In parentheses after this number are the t ratios which show the statistical significance of each of the B values. At the bottom of the table are shown the constant for each equation and the coefficient of determination (R^2). The R^2 and R^2(a) (adjusted) values show the proportion of the variance explained by the equation.

Going back to Table 7, we can illustrate how one can translate into a predictive equation. Using the 1967 equation:

$$\text{IND025} = .921\ (\text{V67004}) + 3.789\ (\text{V67007}) + 1.718\ (\text{V67009}) + 1.008\ (\text{V67010}) + 10.493\ (\text{V67012}) + 1.177\ (\text{V67013}) + 2927.345\ (\text{SMSA67}) + 3361.156$$

If one wishes to predict the assessed value of agricultural land for any county in Ohio using this equation, one need only have the production figures for each of the crop types in the equation and know whether or not the county was in an SMSA. One can interpret each of the tables in a similar fashion. How these equations will be translated into models for use on the state computer system is discussed further in the final chapter of this report.

Several interesting trends are shown by these regression equations. Tables 7 and 8 show that a strong relationship exists between agricultural production and assessed value in both 1967 and 1972. The R^2(a) values for these equations range from .683 to .809. Certain products are shown to be more important in Ohio agriculture. These include hogs, corn, soybeans, greenhouse, and other crops categories.

Viewing the coefficients in these equations, it appears that there were changes in the importance of particular crops between the two years. Thus, the b coefficient for soybeans in 1967 is 1.008 while it is 1.808 in 1972. It may not be true, however, that these two single years are representative of long

Table 7

Assessed Value Agricultural Land*

	1967		1972		
Indep.Variables	B	t ratio	B	t ratio	Indep.Var.
V67004	.921	(3.51)	1.524	(3.95)	V72003
V67007	3.789	(1.44)	29.400	(4.55)	V72007
V67009	1.718	(3.14)	1.808	(8.96)	V72010
V67010	1.008	(1.86)	1.539	(3.03)	V72013
V67012	10.493	(3.97)	5003.686	(3.41)	SMSA72
V67013	1.177	(3.35)			
SMSA67	2927.345	(3.03)			
C(constant)	3361.156		2952.364		C
	.826		.705		R^2
	.809		.691		R^2(a)
Mean	14545.002		19894.229		
Δ Mean		5349.227			

* All coefficients are significant at the.001 level except

V67007 (.2)
V67010 (.1)

Table 8

Total Agricultural Assessed Value*

	1967		1972		
Indep. Variables	B	t ratio	B	t ratio	Indep. Var.
V67007	19.228	(4.21)	1.102	(2.79)	V72002
V67009	3.508	(7.62)	1.873	(3.11)	V72003
V67012	18.474	(4.14)	32.738	(3.30)	V72007
V67013	1.572	(2.50)	1.890	(5.36)	V72010
			7.146	(1.30)	V72012
			2.205	(3.15)	V72013
SMSA67	3827.692	(2.21)	6387.938	(3.07)	SMSA72
C	8781.813		5405.612		C
R^2	.729		.705		R^2
R^2(a)	.716		.683		R^2(a)
Mean	24880.412		30561.794		Mean
Δ Mean		5681.38			

*All coefficients are significant at the .01 level.

Except V67013 (.02)
SMSA67 (.05)
V72012 (.2)

term trends in Ohio agriculture. For this reason data on the annual cash receipts for crops and livestock were collected for 1962 through 1972. Thus, instead of employing the single year cash receipts variable, a six and five year average (1962-1967, 1968-1972) were input into the regression equations. The results are shown in Tables 9 and 10. Here, one can compare the results using the simple totals for one year (V67001, V67008) to the results using the averages (AVLIV67, AVCRP67). Not only do the b coefficients change but also they become stable over time. The coefficient for AVLIV67 is .632 and for AVLIV72 .648 - not significantly different. What this means is that changes in agricultural assessed value from 1967-1972 are accounted for almost entirely by the dummy variables for urbanization - SMSA67, SMSA72. In other words, competition from urban land uses in SMSA counties was bidding up the price and, therefore, the assessed value of agricultural land. To the best of our knowledge, this is the first time that this trend has been demonstrated quantitatively with a predictive equation.

The final set of predictive equations are those for change (delta) in assessed value 1967-72. Here it was found that changes in agricultural production do not explain changes in

Table 9

ASSESSED VALUE AGRICULTURAL LAND*

	1967		1972		
Indep.Var.	B	t ratio	B	t ratio	Indep. Var.
V67001	.490	(5.21)	.531	(4.30)	V72001
V67008	1.175	(11.30)	.910	(7.78)	V72008
C	3488.230		6535.432		C
R^2	.707		.562		R^2
R^2(a)	.704		.557		R^2(a)
AVLIV67	.632	(5.89)	.648	(4.68)	AVLIV72
AVCRP67	1.243	(10.10)	1.272	(8.19)	AVCRP72
C	3120.179		5537.328		
R^2	.695		.589		
R^2(a)	.691		.582		
AVLIV67	.678	(6.54)	.701	(5.35)	AVLIV72
AVCRP67	1.181	(9.89)	1.179	(7.94)	AVCRP72
SMSA67	2986.172	(3.01)	5322.154	(3.48)	SMSA72
C	2191.150		3340.624		
R^2	.725		.639		
R^2(a)	.719		.630		
Mean	14545.002		19894.229		
Δ Mean		5349.227			

*All coefficients are significant at the.01 level.

Table 10*

TOTAL AGRICULTURAL ASSESSED VALUE

	1967		1972		
Indep.Var.	B	t ratio	B	t ratio	Indep.Var.
V67001	.949	(6.08)	.975	(5.81)	V72001
V67008	1.443	(8.17)	.987	(6.15)	V72008
C	8552.664		12179.983		C
R^2	.638		.546		R^2
R^2(a)	.634		.541		R^2(a)
AVLIV67	1.157	(6.22)	1.164	(6.24)	AVLIV72
AVCRP67	1.530	(7.63)	1.404	(6.71)	AVCRP72
C	7965.607		10755.133		C
R^2	.637		.580		R^2
R^2(a)	.633		.575		R^2(a)
AVLIV67	1.256		1.234	(6.97)	AVLIV72
AVCRP67	1.396		1.281	(6.39)	AVCRP72
SMSA67	6423.951		7016.750	(3.40)	SMSA72
C	5967.050		7858.989		C
R^2	.699		.631		R^2
R^2(a)	.692		.623		R^2(a)
Mean	24880.412		30561.794		
Δ Mean		5681.38			

*All coefficients are significant at the.001 level.

Table 11*

DELTA AGRICULTURAL LAND VALUE (1967-72)

Indep. Var.	B	t ratio
CHGLIV	.607	(2.87)
CHGCRP	.891	(3.72)
I021	-1.357	(8.07)
I022	.317	(6.52)
I023	.089	(5.70)
SMSA72	2330.842	(3.08)
C	1817.123	
R^2	.561	
R^2(a)	.534	

Mean (10^3) 5349.227

*All coefficients are significant at the .001 level.

Except CHGLIV (.01)

Table 12*

DELTA TOTAL AGRICULTURAL ASSESSED VALUE (1967-72)

Indep. Var.	B	t ratio
CHGLIV	.792	(3.05)
CHGCRP	.664	(2.26)
I021	-2.072	(10.03)
I022	.294	(4.92)
I023	.165	(8.61)
SMSA72	2299.777	(2.47)
C	2603.019	
R^2	.639	
R^2 (a)	.617	

Mean (10^3) 5681.383

*All coefficients are significant at the .01 level except

CHGCRP (.05)
SMSA72 (.02)

assessed value. This is an expected result since we can assume that overall agricultural production in Ohio is probably near its peak and is only slightly affected by short term fluctuations in the produce market. We would then expect that it is the competition by other land uses for agricultural land which would better explain changes in assessed value. This is demonstrated by Tables 11 and 12. Here, one can see that changes in production combined with changes in the other land categories give a strong estimate of agricultural assessed value.

There are actually several trends which seem to be measured by these equations. First, there is the effect of a slight increase in production. Second, there is the effect of urban land bidding up the prices of agricultural land. This is shown by the SMSA, commercial land, and residential land variables. Third, there is the effect of direct consumption of agricultural land on the urban fringe. This effect seems to be most highly correlated with the industrial land category and is why this coefficient is negative. Finally, it must be pointed out that changes in agricultural building assessed value are almost negligible. The mean change in land value is $5349.227 x 10^3 and in total value is $5681.383 x 10^3 leaving only a change of $332.16 x 10^3. This is because tax assessments between 1967 and 1972 were made exclusively on the basis of market value of land. The value of agricultural buildings for urban uses is negligible. Thus, the strongest equation for delta total agricultural assessed value is generated by using the same variables as those used for the land assessed value equation. This is shown in Table 12.

Implications of the Agricultural Sector Models

The agricultural sector models in combination with those for the other land sectors, allow estimation of the total tax base in Ohio counties. Given projections of population, employment, and agricultural production (input variables) the state will now have a tool to predict the resultant land conversion and tax base.

Another important implication of these models is related to the usefulness of LANDSAT data in land use modeling over time. LANDSAT interpretations can more easily distinguish between agricultural and urban uses than among urban uses. Since the urban and agricultural uses are shown to be interrelated by these models, it follows that LANDSAT can be used directly to monitor changes in agricultural resources due to urbanization and then, to help establish policies which will protect valuable agricultural land. The direct applications of LANDSAT for these purposes will be explored more fully in the final stage of this project.

Taking all of the tax assessment and tax parcel models, alternative scenarios of future development in Ohio can be simulated and their land use tax base impacts can be estimated. In this way, public officials can better anticipate and plan for Ohio's future.

Chapter II

Converting Tax Base Data to Land Use Information

One set of models which was produced during Phase I of this study is that for tax parcels. These models predict the number of tax parcels in each category of land use given projections of population and employment. Data on tax parcels are readily available and would, therefore, be an excellent, continuing source of information. What is needed then is an assessment of whether or not these data can be converted to actual land acreages. One of the major accomplishments during Phase II of the Ohio Land Allocation Model study is just such an assessment. The general approach, methodology, results, and conclusions are explained in this chapter.

Land Acreage from Parcel Data

In order to derive the acreage from data on parcels, one would need to know the size of each parcel. Alternatively, one may derive a frequency or probability distribution of parcel sizes in each county for each land category. This distribution can then be multiplied by the number of parcels in each category in order to get the acreage. Table 13 illustrates how one would calculate the probable acreage of residential land in a hypothetical county based on a sample of sizes of parcels in that county.

Table 13

HYPOTHETICAL DISTRIBUTION OF RESIDENTIAL PARCEL SIZES

SHOWING THE CALCULATION OF ACREAGE

Parcel Size (Acres)	Number in Sample	Frequency	Acreage*
.1	100	.10	250.0
.25	500	.50	3125.0
.50	200	.20	2500.0
.75	100	.10	1875.0
1.00	50	.05	1250.0
1.50	20	.02	750.0
2.5	10	.01	625.0
7.5	10	.01	1875.0
10.0	5	.005	1250.0
11.0	5	.005	1375.0
Total	1000	1.000	14875.0

*Actual total number of residential parcels = 25000 using 0.1 acre size as example

25000 x .10 frequency = 2500 x .1 acres = 250 acres

Sampling Parcel Data

The purpose of the survey undertaken was to gain information about the size of tax parcels in each of the four major land uses and to determine whether or not reliable profiles of parcel sizes could be established. This was done by taking a two percent random sample of the tax parcels in three central Ohio counties: Pickaway (Circleville), Delaware (Delaware), and Licking (Newark). The land use type and acreage for each parcel selected were coded for keypunching and the samples were analyzed using the Statistical Package for the Social Sciences (SPSS).

The source of the parcel information was the public record of appraisal compiled by each county's auditor for 1975. Each parcel record contained the owner's name, an identifying parcel number, a legal description of the parcel, the assessed value of the land and buildings, and in some cases the acreage or dimensions of the parcel. These records are organized in the following way:

Pickaway County

First level - by township or incorporated area
Second level - by school district
Third level - alphabetically by owner's name
Thirteen parcels per page

Delaware County

Same manner as Pickaway, but 35-40 records per page

Licking County (two complete listings)

Alphabetically by owner's name, thirteen records per page

First level - by township or incorporated area
Second level - by school district
Third level - by land use type
Fourth level - alphabetically by owner's name
Sixteen records per page

A random number table with values ranging from 1 to 52 was used to select the parcels to be recorded. In Pickaway and Licking Counties the random number between 1 and 52 identified one record in a four page block. In Delaware County, only values between 1 and 40 were used and each number identified a record for a single page. When a parcel was selected, the land use and acreage of the parcel was recorded with the following exceptions:

1) If the parcel had no acreage recorded, its subdivision name and lot number were noted and the dimensions of the lot taken from the plat record, converted to acres and recorded.

2) If the legal description contained the dimensions of the parcel, e.g. 150' x 250', this information was noted and converted to acres.

3) If the legal description did not identify a subdivison name or contain the dimensions of the parcel, the parcel was rejected and another random number and parcel selected. A deed search is necessary to identify the acreage of such a parcel.

Because industrial and commercial parcels make up a very small portion of the parcels within a county, very few such parcels were selected in the random sampling process. This deficiency was corrected by selecting a township book in an area containing industrial and commercial land and recording all such parcels which showed acreage in the sample until a minimum of fifty parcels were recorded.

The coded information was keypunched and SPSS was used to calculate the frequency distributions and simple statistics for each sub-sample, in both grouped and ungrouped form. Table 14 displays the results of the ungrouped analysis and the sample sizes for each land use and county.

The frequency distributions obtained from the random sample were compared using the Smirnov test. This test was chosen because it does not assume a normally distributed population, and the populations from which the samples were drawn are not normally distributed. The test statistic, called the D value, is the largest difference between the cumulative frequencies for each grouping of the two samples being tested. The samples were grouped as shown in Table 15. If the D value is larger than the critical value, the two samples are significantly different. The samples were compared within land use types, the results are displayed in Table 16. The significantly different samples were the

Table 14

PARCEL SIZE SURVEY SIMPLE STATISTICS (UNGROUPED DATA)

	Pickaway	Delaware	Licking	All Counties
Agricultural Parcels				
N	106	156	235	497
Mean	49.3	40.4	43.4	43.7
Median	32.0	38.1	32.8	34.0
Variance	2791.3	1038.8	1523.9	1644.6
Skewness	1.449	1.668	1.252	1.557
Industrial Parcels				
N	53	73	81	207
Mean	11.3	9.0	23.6	15.3
Median	3.0	3.1	6.0	4.2
Variance	413.0	173.3	1560.1	163.5
Skewness	3.394	2.038	2.285	6.929
Commercial Parcels				
N	52	80	176	308
Mean	3.0	3.5	4.8	4.2
Median	0.8	0.8	0.9	0.8
Variance	139.3	49.9	222.6	163.5
Skewness	6.628	3.429	6.457	6.929
Residential Parcels				
N	240	530	754	1524
Mean	1.0	1.4	0.8	1.0
Median	0.3	0.3	0.2	0.25
Variance	4.2	8.5	3.6	5.5
Skewness	4.404	3.643	6.514	4.783
All Parcels				
N	451	839	1246	2536
*Estimated Total Parcels	18,000	29,000	52,000	99,000
Sample Size	2.5%	2.9%	2.4%	2.6%

*State Board of Tax Appeals

TABLE 15

Group	Land Use Type Agricultural	Industrial	Commercial	Residential
1	.1-.9	.1-.9	.1-.2	.1
2	1.0-9.9	1.0-4.9	.3-.4	.2
3	10.0-29.9	5.0-9.9	.5-.6	.3
4	30.0-49.9	10.0-14.9	.7-.8	.4
5	50.0-69.9	15.0-24.9	.9-1.0	.5
6	70.0-89.9	25.0-49.9	1.0-2.9	.6
7	90.0-109.9	50.0-74.9	3.0-4.9	.7
8	110.0-129.9	75.0-99.9	5.0-6.9	.8
9	130.0-159.9	100.0-149.9	7.0-9.9	.9
10	160.0+	150.0+	10.0-49.9	1.0-1.4
11			50.0-99.9	1.5-1.9
12			100.0+	2.0-2.9
13				3.0-4.9
14				5.0+

Inclusive Group Limits in Acres

Table 16

SUMMARY OF SMIRNOV TESTS

Samples Tested	LAND USE TYPES: AGRICULTURAL		INDUSTRIAL		COMMERCIAL		RESIDENTIAL	
Licking-Delaware	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)
	235	156	81	73	176	80	754	530
Critical Values								
.05 Level	.140		.219		.184		.077	
.01 Level	.168		.263		.220		.092	
D Values	.091		.184		.216*		.158*	
Pickaway-Delaware	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)
	106	156	53	73	52	80	240	530
Critical Values								
.05 Level	.171		.245		.242		.106	
.01 Level	.205		.294		.290		.127	
D values	.139		.184		.135		.094	
Licking-Pickaway	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)	N(1)	N(2)
	235	106	81	53	176	52	754	240
Critical Values								
.05 Level	.159		.240		.215		.101	
.01 Level	.191		.288		.257		.121	
D Values	.102		.061		.081		.215*	

*Significantly different samples

$$\text{Critical Value at .05 Level} = 1.36\sqrt{\frac{N(1) + N(2)}{N(1) \times N(2)}}$$

$$\text{Critical Value at .01 Level} = 1.63\sqrt{\frac{N(1) + N(2)}{N(1) \times N(2)}}$$

D Values = Maximum (Cumulative Frequency(1,i) - Cumulative Frequency(2,i))

i = 1 to number of groups in distribution residential sample for Licking County compared to both Delaware and Pickaway Counties, and the commercial samples for Delaware and Licking Counties. The difference probably resulted from the more urbanized nature of Licking County. Platted parcels are more numerous in urbanized areas and are generally smaller than non-platted parcels.

Conclusions

The three samples taken do not allow generalization of the results to the entire state. However, they do indicate that profiles of different types of counties (urban, rural, metropolitan) could be developed with a sample of 10-15 counties. Sampling this many counties could require as many as 1000 man-hours. However, as more auditors' records become computerized, such a sample could become feasible. If reliable profiles could be developed it would allow translation of the existing number of parcels data to acreage, providing much useful information about land use and land use change. In this way, projections made using the tax parcel models can be directly translated into land use projections.

The results of this type of analysis could then be used as a continuing and consistent check on the accuracy of macro level land use totals produced by LANDSAT. Future work with the tax models and continued use of LANDSAT could generate a data base in the future which directly linked land use change as measured by LANDSAT with the changes in tax base in Ohio Counties.

Chapter III

Land Conversion in Franklin County
Establishing a Test for LANDSAT Data

LANDSAT offers the opportunity to provide computer compatible land use information at frequent intervals. Thus, land use changes as measured by LANDSAT can be linked with changes in population, employment, and other socio-economic characteristics to produce empirical models of land use change. This is the underlying goal of the modeling effort in the State of Ohio. In pursuing this goal, a number of technical problems have arisen which require further exploration before a set of final models can be produced. This chapter summarizes the work using aerial photography for Franklin County, Ohio, which will be utilized in performing a test of the accuracy of LANDSAT interpretations.

Land Use Modeling and LANDSAT

In order to create a predictive land use model for counties in Ohio, a land use data base is required which is both extensive and accurate. LANDSAT provides a unique opportunity for such modeling because it is the most extensive, most consistent data base available. Unfortunately, a number of technical problems arise in converting from LANDSAT imagery to land use categories. These problems leave a potential for large errors in the final land use classifications.[10] Such errors would be unacceptable for the purpose of land use modeling, i.e. relating land use changes to socio-economic changes. Thus, the first step in analyzing LANDSAT must be to identify the nature and degree of these errors, and if possible, to derive correction factors which might be applied prior to the use of these data in a model.

The potential errors associated with LANDSAT have been subdivided into two major components. Those errors associated with the misalignment of pixels for two different LANDSAT scenes are referred to as Error 1. This error results from the possibility of ± one pixel misalignment in ground orientation as a result of the rescanning readjustment, and reclassification of the original, distorted data pixels.[11] The second type of error (Error 2) results from the misclassification of land cover due to the similarities in spectral signatures of different land uses. To date, the nature and extent of these errors have not been quantified. This is the first task of LANDSAT data analysis in Ohio.

[10] Space Applications Board, Assembly of Engineering, Nat. Res. Council, Supporting Paper 3 Land Use Planning (Washington, D.C. Nat. Acad. Sci., 1974), pp. 31-32.

[11] Bendix Aerospace Division, Computer Mapping of LANDSAT Data for Environmental Applications (Ann Arbor, Michigan: Bendix Corporation, November 1975), p. 8.

Quantifying LANDSAT Errors

In order to quantify the misclassification errors associated with LANDSAT, a number of tests have been devised. The first test relates to the overall changes in land use which can be tabulated from LANDSAT data. Scenes for Franklin County for both 1973 and 1975 will be interpreted by Bendix Corporation and given to the State of Ohio on computer tapes. Based on these tapes, one can calculate the changes in land use in Franklin County during this period. The question which arises is how accurate are these land use change figures? Since LANDSAT has been in use for such a short time, no one appears to have utilized the data in this way or to test the accuracy of the results.

Fortunately, two sets of aerial photographs are available for Franklin County at times very close to those for LANDSAT imagery. Thus, the first step in compiling information for a test of LANDSAT involved the interpretation of land use change from these aerial photographs.

The initial task was to correlate the 1972 Franklin County aerial photographs (scale 1:1000) with the 1976 set (scale 1:2000). Upon completion and matching of the comparable mosaics with differing scales, the photographs were scanned on a zoom transfer scope for land use changes. Any differentials apparent in the two sets of photos were noted on the 1972 photos. We attempted to identify the entire area of change during this process, noting not merely the existence of a new structure but also its attendant property lines, if they could be identified from the landscaping. As we were interested in land use changes only, differing crop patterns and water levels were considered extraneous.

Categorization of land use changes appeared under seven classifications: 1) Urban Recreation 2) Open Space - all land void of development that could not be identified as agricultural land 3) Agriculture 4) Commercial - including trucking, airports, and warehousing operations 5) Industrial 6) Residential 7) Public - including schools, churches, and highways. A separate notation of "A" was utilized to signify land cleared and/or under construction and would be appended to the proper land use symbol.

Upon comparison of the areas on the 1972 set of aerial photos with the actual changes in the 1976 photos, each land use change was catalogued as outlined above, with the 1972 land use recorded a separated from the recorded 1976 land use change by a slash (e.g. 3/6). Certain decision rules were derived for classification of land uses as follows:

1) Commercial buildings - a higher parking lot to building ratio than industrial structures. Location along a major arterial. Location as related to residential development.

2) Industrial - location near interstate interchanges. Parking lot to building ratio lower than commercial. Landscaping and large front set back.

3) Additional buildings on a previously established land use was not noted, except in the case of new residential units in subdivision development.

4) Individual parcels in subdivisions cleared for development in 1972 and developed by 1976 were noted as 6A/6.

5) Agriculture - clear crop pattern with evidence of farm buildings in close proximity.

Once the classification was completed and noted on the 1972 photos, a planimeter was used to determine the areal change. Thus, a table was derived detailing for each 1972 photo the land use changes on the photo with its before/after classifications, the area of land use change in square inches, and finally, this square inch measurement converted into acres. Table 17 shows these data.

In order to quantify the errors associated with LANDSAT at the pixel level, we made use again of the aerial photographs. First, the photos were oriented to the U.S.G.S. quadrangles using a zoom transfer scope. Then, a 1.1 acre grid of the same dimensions as LANDSAT pixels was overlayed on the mosaic of photos for

Table 17

LAND USE CHANGES IN FRANKLIN COUNTY BETWEEN 1972 AND 1976
(In Acres)

From \ To	Urban Recreation	Open Space	Agriculture	Commercial	Industrial	Residential	A* Residential	Public	Total
A* Urban Recreation	4.591								4.591
Open Space	136.823			1,154.270	637.052	4,210.055	328.053	686.869	7,153.122
Agriculture	344.582			366.850	709.826	2,278.466	219.927	61.983	3,981.634
A* Agriculture			16.758						16.758
Commercial								4.591	4.591
A* Commercial				196.281					196.281
Industrial		5.510							5.510
A* Industrial					220.156				220.156
Residential		8.724		68.871	14.233			20.202	112.030
A* Residential						2,542.470			2,542.470
A* Public								367.080	367.080
TOTAL	485.996	14.234	16.758	1,786.272	1,581.267	9,030.991	547.980	1,140.725	14,604.223

A* - under construction and/or land cleared for development

Source: 1972 (Flight No. 5010) and 1976 (Flight No. 5979) aerial photos of Franklin County with field checks.

each year, for a sample quadrangle in Franklin County. For each "pixel" the dominant land cover (greater than 50%) and the probable land use, if different, was recorded, encoded, and punched onto computer cards. In this way, a set of highly accurate land use information was produced which is compatible with the format of the LANDSAT data. When the LANDSAT data become available, a computer generated pixel by pixel comparison may be made of land cover differences, and a quantified index of Error 2 can be generated.

Chapter IV

Study Design for the Final Phase

During the final phase of the project, a number of additional tasks will be accomplished. The first of these is the tests of the accuracy of LANDSAT data. Error 2 will be quantified by comparison with the aerial photograph "pixel" data described in Chapter III.

Identifying Error 1 is a much more difficult task. Ideally, one would take two scenes of the same area with a small time gap between them (e.g. 18 days). Any changes in land use recorded for this time gap would have to be due to misalignment since a real change is unlikely. Unfortunately, different weather conditions, sun angles, etc. can produce two distinct sets of spectral signatures in eighteen days. Thus, errors identified over this period would be due not only to misalignment but also misclassification and changes in the training set. For the purposes of this study then, we will analyze a one day "gap." This will consist of the one day side lap area for Franklin County. In one day, spectral signatures are not likely to change. Yet problems with aligning these two different scenes will occur and should be reflected in this overlap area. To the extent that this overlap is not a true measure of the alignment problems which occur from year to year, we will not identify the misalignment error. However, it is felt that this analysis will shed some light on this problem.

Correcting LANDSAT Errors

Given a determination of the errors associated with LANDSAT, the next step will be to see if these errors are consistent. For example, it may be that certain types of agricultural land are consistently identified as urban. There may be a definitive percentage of error in urban categories across all types of errors. Given this information, error correction factors can be derived and applied to all LANDSAT data in Ohio.

Not only can the aerial photo data be used to develop correction factors for the LANDSAT data provided by Bendix Corporation, but they can also be utilized to test the relative accuracy of other methods of LANDSAT computer compatible tape data analysis. Thus, one could reinterpret the Franklin County LANDSAT tapes with additional, new, or revised techniques and algorithms utilizing the data gathered in the course of this project as the baseline, "real world" measure of accuracy.

It would be expected that all methods of interpretation would base some level of inaccuracy for the reasons discussed above. However, the method of analysis and data presented in this report would help to delineate the level of error associated with a number of alternative interpretation techniques.

Deriving a Land Use Model

Once error correction factors have been derived and applied to LANDSAT, the data can be utilized to generate a set of land use models. Regression analysis will be used to determine the amount of land in each county in each use as a function of socio-economic characteristics in the same time period. The nature of these models will be the same as those derived in Phases I and II of this project.

Conclusions and Model Outputs

Having performed all of the tasks briefly outlined above, a number of useful outputs will be produced. First, a quantitative definition of the errors associated with current LANDSAT interpretation will be made. This can be used to point to areas where further technical development is required. Second, the State of Ohio will have a measure of the accuracy of its LANDSAT interpretations and a set of error correction factors. Finally, LANDSAT data will be linked in a modeling framework with social and economic data. This model can be utilized in land use planning efforts at the state, regional, county, and local levels.

It will then remain to supervise the programming and mounting of each of the computer models produced during the course of the study, on the state computer system. Table 18 shows models on tax base produced in Phase I of the project. In addition to these 34 models, there will be three additional models of agricultural assessed value and at least one model of LANDSAT land use change (assuming the accuracy level is acceptable.

Each of these models will be documented as follows:

1. Explanation of what the model predicts.
2. Explanation of the required input variables.
3. Specification of formats for input variables in card deck.

Table 18

PROPOSED GENERAL FORM FOR TAX MODELS

Potential Models

Static Models		Change Models
1	Residential Parcels	18
2	Commercial Parcels	19
3	Industrial Parcels	20
4	Agricultural Parcels	21
5	Residential and Commercial Parcels	22
6	Residential AV Land	23
7	Residential AV Total	24
8	Commercial AV Land	25
9	Commercial AV Total	26
10	Industrial AV Land	27
11	Industrial AV Total	28
12	Agricultural AV Land	29
13	Agricultural AV Total	30
14	Residential and Commercial AV Land	31
15	Residential and Commercial AV Total	32
16	All Taxable Land AV	33
17	All Taxable Total AV	34

For a run of one or more models, the user would prepare a card deck containing the following data:

Card 1 - number of counties to be processed

Card 2 - name of 1st county

Card 3 - number of models desired (NEQS) and the index number of each model equation

Card 4 through (3 + NEQS) - input values for each model requested

End of file marker or repeat of Cards 2 through end for each additional county.

In this way, one can forecast the tax base, parcel numbers, and land use for up to 88 counties in Ohio utilizing input projections of population, employment, agricultural production, and the SMSA dummy variables. One can select to use only those models which are relevant to a particular project. Alternative projections of population, employment, and the other input variables can be used to simulate the potential impacts on the property tax base and land use.

These models can also serve as control totals for land use and tax changes at the county level. Then, further model development may be carried out at the micro level to yield additional allocation procedures. All of the models should thus serve to aid the work of public officials and planners at the local, regional, and state levels.

APPENDIX A

AN ANALYSIS OF THE PERFORMANCE OF THE DEMOS MODEL

Introduction

The major purpose of the State's land use modeling effort is to find a functional relationship between variables to land use and land use change (dependent variables) and variables related to economic and demographic characteristics of the state (explanatory variables independent variables). The explanatory variables include employment by category, population size, and the changes in those variables over time, at the county level. The report on Phase I details the statistical analysis which was required to define the mathematical relationships among the dependent and independent variables.

Given a forecast of the economic and demographic variables and using these mathematical equations, it is possible to predict the new patterns of land use, land use changes, and thus, to analyze the level of pressure of land use conversion in each county. The accuracy of the prediction will depend not only on the specification and statistical performance of the functional equations in the land use model, but also on the performance of the State's model for forecasting economic and demographic variables at the county level. It is for this reason that we were asked to undertake an analysis of DEMOS, the model the State currently uses for these projections. The results of this analysis are summarized below.

The DEMOS Model

DEMOS, a model developed by Battelle Memorial Institute, is the model used by the State to forecast economic and demographic variables. Given two key input parameters the national unemployment rate and a population growth rate (assumed to be either slight or no growth), DEMOS predicts employment in thirty-nine categories and population by age group, all at the county level. The projections are made for each county taken one at a time and can be derived for all 88 Ohio counties. The starting date or base period for the model is 1970 and the projections can be made on an annual basis to 1985. Table A-1 shows an example set of projections for one Ohio county. Because population change variables are not used in the land use change model equations, only the DEMOS employment projections were analyzed.

Testing Performance of DEMOS

For the four year period 1970-1974, DEMOS projections can be considered to be estimates of employment in each county. Thus, estimates were made for all 88 counties in Ohio for 1972 and 1974 using actual national unemployment rates for these years and assuming the zero population growth rate which has occurred over the past few years. These estimates can be compared with real counts of employment by county during the same period available from the Ohio Bureau of Employment Services (OBES). An analysis of the performance of DEMOS can be made if appropriate aggregation of DEMOS categories into OBES categories is carried out.

TABLE A-1. Example DEMOS Forecast

POPULATION BY 5-YEAR AGE GROUP, RICHLAND COUNTY, 1972

TOTAL	133,596	0-4	11,659	5-9	12,700
10-14	13,959	15-19	12,885	20-24	10,696
25-29	9,447	30-34	8,455	35-39	7,737
40-44	7,780	45-49	7,787	50-54	7,183
55-59	6,166	60-64	5,170	65-69	4,156
70-74	3,162	75 +	4,654		

EMPLOYMENT BY INDUSTRY, RICHLAND COUNTY, 1972

TOTAL	51,926
AGR,FORESTRY & FISHING	906
MINING	55
CONSTRUCTION	2,306
FURNITURE, LUMBER, WOOD	253
METALS INDUSTRY	5,650
MACHINERY, EXCEPT ELECTRICAL	1,796
ELECTRICAL MACHINERY	6,857
TRANSPORTATION EQUIPMENT	1,497
OTHER DURABLE GOODS	2,860
FOOD AND KINDRED PRODUCTS	216
TEXTILES AND TEXTILE PRODUCTS	197
PRINTING AND PUBLISHING	1,104
CHEMICALS	80
OTHER NONDURABLE GOODS	2,381
RAILROAD AND RAILWAY EXPRESS	172
TRUCKING	979
OTHER TRANSPORTATION	180
COMMUNICATIONS	857
UTILITIES AND SANITARY SERVICE	437
WHOLESALE TRADE	1,690
FOOD AND DAIRY STORES	1,098
EATING AND DRINKING PLACES	1,714
GENERAL MERCHANDISING	1,802
MOTOR VEHICLE RETAILING	965
OTHER RETAIL TRADE	2,089
FINANCE	563
INSURANCE AND REAL ESTATE	1,502
BUSINESS AND REPAIR SERVICES	1,236
PRIVATE HOUSEHOLDS	491
OTHER PERSONAL SERVICES	1,429
ENTERTAINMENT	301
HOSPITALS	1,335
OTHER HEALTH SERVICES	920
GOVERNMENT EDUCATION	2,260
PRIVATE EDUCATION	528
OTHER EDUCATIONAL SERVICES	176
RELIGIOUS AND NONPROFIT ORGS	653
PROFESSIONAL ORGANIZATIONS	675
PUBLIC ADMINISTRATION	1,716

The DEMOS output was aggregated down to seven categories equivalent to those of OBES. These are shown in Table A-2 being in general terms four basic activities and three non-basic.

TABLE A-2. Bureau of Employment Services (OBES) Employment Categories

Mining	Wholesale and Retail Trade
Contract Construction	Finance, Insurance and Real Estate Services
Manufacturing	
Transportation and Utilities	

Comparisons were made for two sub-periods, 1970-1972 and 1972-1974 in order to test the sensitivity of the DEMOS model to national trends.

It was recognized from the outset that DEMOS projections of employment are based on place of residence while those of OBES are based on place of work. This made direct comparison of category by category employment figures for each county impossible. However, the changes in each set of data (e.g., OBES 1970-72; DEMOS 1970-72) should exhibit exactly the same trends if the DEMOS employment projections are accurate.

The statistical analysis performed was to regress in a cross-sectional way, the change (Δ) employment for the sub-period (1970-72 or 1972-74), to employment at the start of the sub-period. Functionally, it is expressed as:

$$\Delta X_i^d \ (70\text{-}72) = A_i^d \ X_i^d \ (70) \qquad R_d^2$$

$$\Delta X_i^d \ (72\text{-}74) = A_i^d \ X_i^d \ (72) \qquad R_d^2$$

where

ΔX_i^d = change in (Delta) employment in category i given by DEMOS

X_i^d = employment in category i given by DEMOS at the start of the sub-period

i = employment categories (1, 2, 3,...7)

A_i^d and R_d^2 are defined below.

\# of observations = 88

Two statistical parameters are important in this analysis:

1) The regression coefficient A_i can be interpreted as the state's average growth rate of the economic sector i or in other words, how much of the growth is common to all the counties independent of their internal and local attributes. By internal and local attributes we mean such things as industrial attractiveness, agglomeration economies and economies of scale, all of which vary widely from county to county.

2) The coefficient of determination R^2 (R_d^2) can be interpreted as how much of that average growth in the sector is tied to the state's growth. The lower the R^2, the more important are the local attributes in explaining growth and thus changes in population and employment. The larger the R^2, the less important are these local attributes. In general, we can expect that for the basic sectors, the local attributes are important, i.e. we will obtain a lower R^2.

TABLE A - 3

Results of Analysis

SECTOR	i	St	1970 - 1972 OBES	1970 - 1972 DEMOS	1972 - 1974 OBES	1972 - 1974 DEMOS
Mining	1	A i	.216	.008	-.009	-.008
		R^2	.54	.92	.002	.75
Const.	2	A i	-.007	.004	-.0006	-.017
		R^2	.002	.92	.00004	.87
Manuf.	3	A i	-.086	.027	.029	.026
		R^2	.84	.96	.40	.996
Transp.	4	A i	-.035	.004	.004	.015
		R^2	.39	.80	.02	.88
Wholesale	5	A i	.067	.007	.060	.014
		R^2	.71	.34	.85	.71
Financial	6	A i	.102	.007	.039	.014
		R^2	.81	.66	.66	.75
Services	7	A i	.773	.007	.097	.015
		R^2	.99	.51	.98	.75
Total		A i	.066	.013	.048	.018
		R^2	.70	.87	.88	.91

The same analysis was performed on the OBES data.

$$X_i^o\ (70\text{-}72) = A_i^o\ X_i^o\ (70) \qquad R_o^2,$$

$$X_i^o\ (72\text{-}74) = A_i^o\ X_i^o\ (72) \qquad R_o^2,$$

where the symbols represent the same parameters for the OBES data.

The A_i^o's and R_o^2's of this analysis can be used as benchmark figures to compare against the A_i^d's and R_d^2's of the previous step. In this way the performance of DEMOS can be analyzed.

The results of the statistical analysis show a large discrepancy between DEMOS estimates and OBES benchmark figures. This is demonstrated in Tables A-3 and A-4. As an example we can take the manufacturing sector. In the sub-period 1970-72, OBES shows a substantive decrease (A = .086; A_i^d = .029) in manufacturing employment against a gain by DEMOS. Comparing the R^2 values, we see that OBES shows that on 40% (R_o^2 = 40) of the variation of the growth rate all of the growth of the sector (R_d^2 = 996 or 99.6%) is common across the counties without any consideration of local conditions.

Conclusions

Comparison of DEMOS projections for the period 1970-74 with actual employment data for the same period has shown the model to make substantial errors. Population projections could not be analyzed because no actual population counts are available for the years other than 1970. Use of these projections to simulate land use changes based on the equations derived in the present project would thus lead to erroneous expectations with regard to land use change. Thus, the use of the DEMOS model employment projections for this purpose is not recommended.

TABLE A-4

Differences Between DEMOS and OBES Predictions

	1970 - 1972				1972 - 1974			
	OBES		DEMOS		OBES		DEMOS	
Mining	.216	.54	-.008	.92	.009	.002	-.008	.75
Construction	-.007	.002	.004	.92	-.00006	.00004	.017	.87
Manufacturing	-.086	.84	.027	.96	.029	.40	.026	.996
Transportation	-.035	.39	.004	.80	.004	.02	.015	.88
Wholesale	.067	.71	.007	.34	.060	.85	.014	.71
Financial	.102	.81	.007	.66	.039	.66	.014	.75
Services	.773	.99	.007	.51	.097	.98	.015	.75
Total	.006	.70	.013	.87	.048	.88	.018	.91
	G R	R^2	G R	R^2	G R	R^2	G R	R^2

APPENDIX B

The Newling Model: Testing a Method For

Forecasting Population for Minor Civil Divisions

By
Harvey Curran

INTRODUCTION

The purpose of this study was to find a quick and dirty method of forecasting future population for minor civil divisions (MCD's). Population forecasting seems important because it forms the basis for much long-range planning. Quick and dirty methods are desirable because the time and expensive computing machinery to do rigorous work may not be available to a planner who needs a forecast. Minor civil division projections are desirable because available forecasts are for SMSA's or counties rather than MCD's. A survey of population forecasting literature led to the method developed at Rutgers University by Michael Greenberg and others using the Newling density model.[1]

The Greenberg-Newling method is appealing for several reasons. It requires little input data, the calculations can be performed on any calculator capable of exponentiation, and the method allows the forecaster to incorporate his/her knowledge of special conditions. The major question about the method is its accuracy. To test the method, I followed the Greenberg example for calculating the model parameters using Ohio data and applied the results to each township and community in the Miami Valley planning region. This region was chosen because it includes a representative variety of rural, suburban, and urban areas. The following sections present the Newling model, the procedures used to calculate the parameters, and the results of applying the model to the Miami Valley region.

THE NEWLING MODEL

This entire section is taken directly from Seciton 4.2 of the Greenberg book.[2]

The Newling method involves the derivation of critical population densities for urban, suburban, and rural MCD's. All communities are classified and will converge to one of the critical densities, some like older central cities by losing population, others like former farmlands adjacent to central cities by gaining population. Eventually all of the MCD's in the region will approach a steady state of clearly defined rural, suburban, or urban densities.

Newling originally developed his model after observing an inverse relationship between relative population growth from 1950 to 1960 and population density in 1950. This relationship is expressed in Equation 2.1.

Eq. (2.1) $$(1+r_{d_t}) = Ad_t^{-k}$$

where $(1+r_{d_t})$ is the growth ratio, i.e. the rate of growth at each density for a given density ceiling group,

A is a constant for each density ceiling group. It is the growth ratio when the density is one person per unit area,

K is a constant for each density ceiling group. It is the ratio of the rate of change of growth to the rate of change of density, and

d_t is the density at time t.

The density at one time period forward (d_{t+1}) may be expressed as

Eq. (2.2) $$d_{t+1} = (1 + r_{d,t})d_t \ ,$$

or, $$= Ad_t^{-k}d_t$$

which may be simplified as

Eq.. (2.3) $$d_{t+1} = Ad_t^{1-k} \ .$$

Equation (2.3) may be generalized for time (t+m) where m is any number of intervals.

$$\text{Eq. (2.4)} \quad d_{t+m} = A^{1/k} \frac{d_t^{(1-k)^m}}{(A^{1/k})^{(1-k)^m}}$$

The expression within the large brackets approaches unity as (m) becomes very large. Thus $(A^{1/k})$ is the critical density. Each MCD's future densities are related to its initial density (d_t), the critical density $(A^{1/k})$ of its density ceiling group, and the rate (k) at which all members of the group approach the critical density.

Newling determined the parameters (A) and (k) for three groups of counties by least squares. All communities were classified with reference to their density in 1950 and growth rate from 1950 to 1960 by partitioning the scattergram into segments equally removed from the regression lines. The density of each unit is projected by substituting into Equation (2.4) the appropriate (A) and (k) values and its population density in 1960 as the value of (d_t).

In essence, density acts as a surrogate for a host of previously cited factors responsible for the suburbanization process. For example, the procedure can subsume the decline of old densely developed central cities, the rapid increase and then the leveling off of suburbs, the preservation of lands in rural land uses, and other commonly observed phenomena.

DEVELOPING (A) AND (K) PARAMETERS FROM OHIO DATA

Following the example of Newling and Greenberg, We used least squares regression to determine the (A) and (k) parameters for rural, suburban, and urban density ceiling groups using data from Ohio counties. The first step in the process is to make a scattergram of the natural log of the 1950 density for each Ohio county against the natural log of the average decade growth rate between 1950 and 1970 for each county. The average decade growth rate is defined as

Eq. (3.1) GROWTH = 1970 Population / 1950 Population

If GROWTH $>$ 1 then GROWTH = (GROWTH-1)/2 + 1 and

If GROWTH $<$ 1 then GROWTH = (1-GROWTH)/2 + GROWTH.

The resulting scattergram was examined for linear groupings and divided into three groups. Least squares regression was performed on these three data groups with outlying points being eliminated to improve the fit. The regression equations which resulted and their R^2 and F values are displayed in table 3.1.

TABLE 3.1 Regression Equations Developed from Ohio Data

Log(GROWTH) = a + B*Log(1950 Density)

Class	a	b	R^2	F
Rural	.97718	-.22889	.71	37.8
Suburban	1.19257	-.24196	.86	84.6
Urban	.97767	-.1167	.90	102.[illegible]

The parameters (A), (k), and ($A^{1/k}$) were developed from the regression coefficients using the relations in Equation (3.2).

Eq. (3.2) (A) = antilog(a)

(k) = -B.

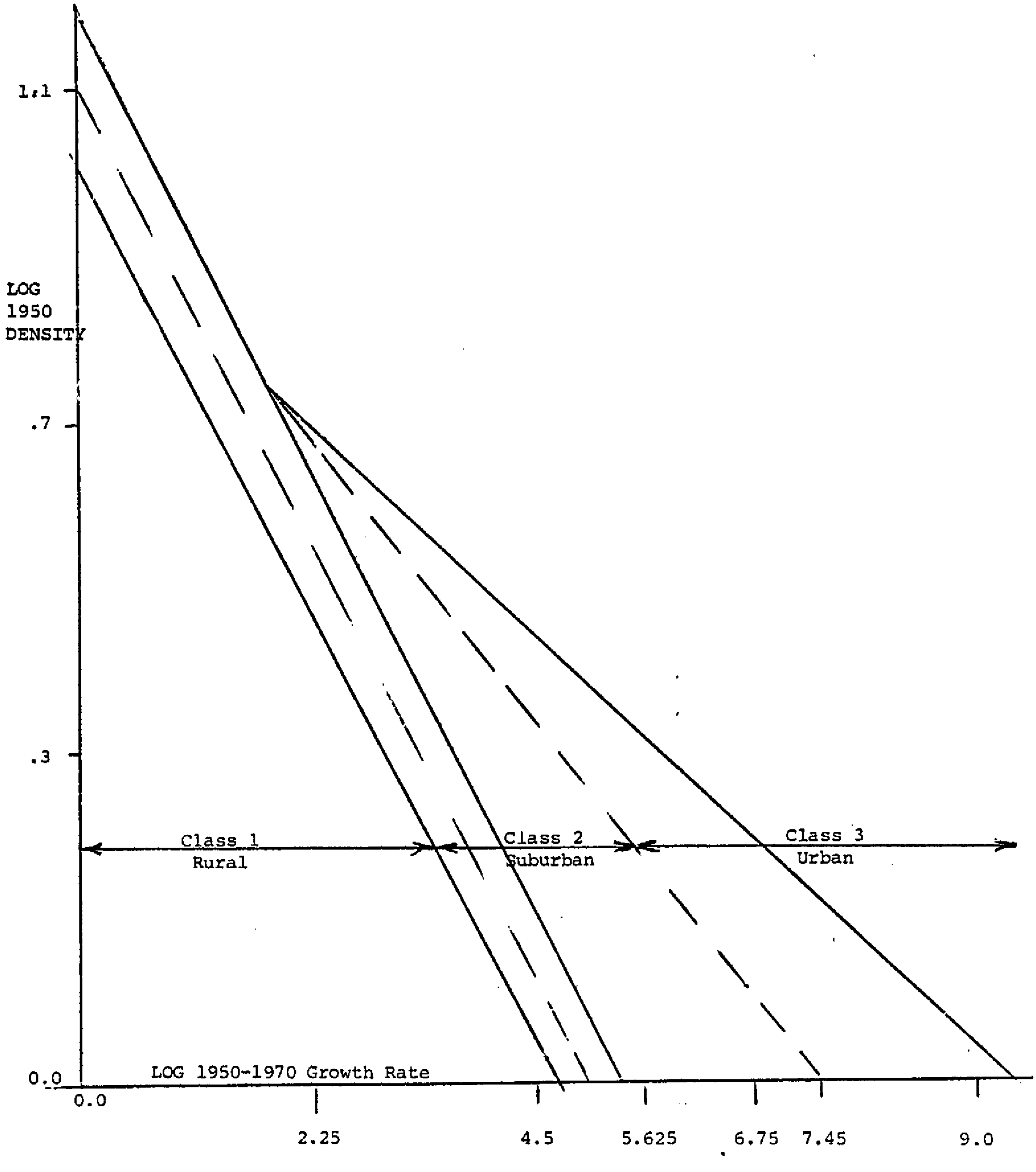
Table 3.2 displays the (A) and (k) parameters for each density ceiling class along with the critical densities.

TABLE 3.2 (A) and (k) Parameters and Critical Density

Class	A	k	Critical Density
Rural	2.657	.22889	71.47 (persons/sq. mi.)
Suburban	3.2955	.24196	138.21
Urban	2.6583	.1167	4348.70

The regression equations were graphed and the graph divided into sections for use in classifying the MCD's to be forecasted. Figure 3.1 displays the subdivided graph of Log(1950 Density) against Log(GROWTH). The solid lines are the regression lines and the dotted lines are the dividers between density ceiling classes.

FIGURE 3.1 Subdivided Graph for Determination of Density Ceiling Classes



TESTING THE NEWLING METHOD

The input data necessary for the Newling model was collected from the 1950 and 1970 Censuses of Population and the Ohio Department of Natural Resources OCAP system. The input data set consists of the 1950 population, the 1970 population, and the area of each MCD. The first step in applying the model is the classification of MCD's by density ceiling classification. The 1950 density in persons per square mile and the average decade growth rate were calculated, the natural log of each value taken, and the result displayed. (See Table 4.1) The graph in Figure 3.2 was then used to classify the MCD's. The appropriate (A), (k), and 1950 density were then substituted into Equation (2.4) and the predicted density calculated for each MCD in 1970, 1980, and 1990. $(m = 2,3,4)$ The results of these calculations along with the actual census count for the MCD in 1970 are displayed in Table 4.2.

RESULTS OF THE TEST

The accuracy of the method was then tested by calculating the percentage error between the 1970 forecast and the actual 1970 population. The results of these calculations are displayed in Table 5.1. A summary of the magnitude and direction of the errors is displayed in Table 5.2.

All of the large errors (over 50%) except one are under estimates. The one over estimate resulted from a change in the boundaries of the MCD. The large under estimates are all for MCD's which experienced extremely high growth rates between 1950 and 1970. Greenberg et al recognize this weakness and suggest that two to three time periods are necessary for the model to reach the actual growth of the MCD.[4] A method for correcting the error based on proportional replacement of county

TABLE 4.1 Parameters used to determine MCD class

MCD NAME	LOG(1950 Density)	LOG(50-70 Growth)
Allen	3.83	.070
Wabash	3.79	.021
Jackson	4.60	.063
Patterson	3.77	.045
Brown	4.17	.010
Wayne	4.58	.012
Washington	3.54	-.004
Greenville Twp.	5.41	.016
Adams	4.35	.036
Liberty	3.63	.010
Neave	3.75	.155
Franklin	3.92	-.013
Harrison	4.11	.040
Butler	3.67	.099
Twin	4.65	.109
Monroe	4.00	.093
Arcanum	7.31	.141
Versailles	7.41	.160
Union City	8.02	.056
Greenville	7.54	.181
Ansonia	7.75	.091
Bath	6.47	.378
Beaver Creek	4.68	1.096
Ceasar Creek	3.52	.082
Cedarville Twp.	4.11	.199
Jefferson	3.69	.011
Miami	5.09	.178
New Jasper	3.62	.185
Silver Creek	4.53	.110
Spring Valley	3.83	.145
Sugar Creek	4.09	.114
Xenia Twp.	5.86	-.325
Cedarville	7.47	.341
Jamestown	7.85	.153
Yellow Springs	7.37	.261
Bellbrook	4.87	.689
Fairborn	7.01	.938
Xenia	7.64	.396
Newberry	4.93	.078
Washington	6.63	.089
Spring Creek	4.08	.165
Newton	4.15	.054
Concord	6.15	.157
Staunton	3.91	.659
Brown	3.93	.016
Lost Creek	3.71	.088
Union	4.85	.279
Monroe	5.15	.361
Bethel	4.22	.326
Elizabeth	3.66	.120
Pleasant Hill	7.60	.044

TABLE 4.1

MCD NAME	LOG(1950 Density)	LOG(50-70 Growth)
West Milton	7.18	.322
Piqua	8.06	.090
Troy	7.51	.267
Tipp City	7.11	.239
Bradford	7.70	-.016
Covington	7.43	.089
Butler	5.33	.709
Clay	4.94	.229
German	4.94	.212
Harrison	8.05	.213
Jackson	4.46	.105
Jefferson	5.97	-.029
Madison	6.20	.466
Mad River	7.32	.547
Miami	6.50	.446
Perry	4.56	.331
Randolph	5.53	.885
Wayne	4.44	2.051
Brookville	6.98	.503
Germantown	6.52	.281
Trotwood	5.33	1.330
West Carrolton	6.21	.862
Union	5.38	1.693
Centerville	4.55	1.909
Englewood	5.27	1.843
Dayton	8.63	-.0006
Kettering	7.09	.731
Miamisburg	6.83	.512
Oakwood	8.38	.021
Jefferson	4.22	.238
Monroe	4.09	.045
Harrison	4.58	.114
Jackson	3.56	.005
Washington	4.97	.138
Twin	4.04	.151
Lanier	4.26	.169
Israel	3.62	.038
Somers	4.20	.130
Gratis Twp.	4.23	.244
New Paris	7.35	.269
Lewisburg	7.73	.123
Camden	6.83	.178
West Alexandria	7.81	.145
Eaton	6.93	.190

TABLE 4.2 Newling Method Population Projections for Miami Valley Planning Region

MCD NAME	1970 Count	1970 Estimate	1980 Estimate	1990 Estimate
DARKE COUNTY				
Allen	1517	1580	1868	2045
Wabash	1022	1192	1434	1584
Jackson	2978	2308	2035	1901
Patterson	1448	1622	1965	2181
Brown	1931	1970	2047	2089
Wayne	3736	3471	3966	4234
Washington	1074	1456	1927	2244
Greenville Twp.	15849	9606	7989	7300
Adams	3027	2728	2644	2599
Liberty	1278	1625	2080	2378
Neave	1311	1213	[illegible]83	1654
Franklin	1237	1461	1669	1794
Harrison	2205	2176	2316	2396
Butler	1623	1715	2162	2452
Twin	3623	3312	3683	3885
Monroe	1634	1529	1699	1799
Arcanum	1993	1933	2676	4204
Versailles	2441	2241	3010	4535
Union City	1808	1754	1956	2276
Greenville	12380	10656	13773	19671
Ansonia	1044	1007	1220	1593
GREENE COUNTY				
Bath	38474	30498	54654	122903
Beaver Creek	26555	12001	37079	177705
Ceasar Creek	1071	1240	1655	1936
Cedarville Twp.	3346	2475	2628	2715
Jefferson	1179	1459	1825	2060
Miami	5848	3936	3703	3595
New Jasper	1085	1004	1287	1473
Silver Creek	2907	2789	3249	3500
Spring Valley	2136	2941	2294	2511
Sugar Creek	8276	4047	14989	92387
Xenia Twp.	7912	11977	8372	7026
Cedarville	2342	1576	2076	3044
Jamestown	1790	1512	1779	2229
Yellow Springs	4624	3610	4904	7504
Bellbrook	1268	918	2675	11816
Fairborn	32264	10589	16054	28620
Xenia	25373	15153	18995	26002
MIAMI COUNTY				
Newberry	6598	5675	5673	5673
Washington	22402	9176	4776	3469
Spring Creek	2123	1684	1810	1882
Newton	2947	2788	2922	2996
Concord	19056	8448	5275	4189
Staunton	3863	2081	3083	3737
Brown	1621	1799	2049	2199
Lost Creek	1409	1493	1851	2080
Union	9413	5910	6081	6167
Monroe	9170	4472	4113	3948
Bethel	4284	3260	4268	4869

TABLE 4.2 (con't)

MCD NAME	1970 Count	1970 Estimate	1980 Estimate	1990 Estimate
MIAMI COUNTY (con't)				
Elizabeth	1456	1487	1879	2134
Pleasant Hill	1025	1114	1[illegible]11	1960
West Milton	3696	2732	3934	6539
Piqua	20741	18690	20564	23483
Troy	17186	12913	16851	24391
Tipp City	5090	4366	6430	11009
Bradford	1240	1487	1828	2436
Covington	2575	2673	3576	5324
MONTGOMERY COUNTY				
Butler	19890	12673	32110	11682[illegible]
Clay	7438	4886	4865	4856
German	7102	4786	4760	4747
Harrison	34176	30046	33182	38087
Jackson	5823	3781	4529	4947
Jefferson	11790	8040	5388	4430
Madison	29087	21440	41624	104614
Mad River	43881	22523	31087	48638
Miami	38705	27526	48807	108148
Perry	6020	3943	4542	4868
Randolph	20971	10195	24331	81459
Wayn.		4561	15158	80394
Brookville	4403	2592	3966	7160
Germantown	4088	1262	685	508
Trotwood	6997	2084	5286	19267
West Carrolton	10748	4628	8961	22437
Union	3654	716	1790	6393
Centerville	10333	1919	6180	31377
Englewood	7885	1342	3467	12955
Dayton	243601	230801	213901	192244
Kettering	69999	29471	43683	75462
Miamisburg	14797	8901	14294	27600
PREBLE COUNTY				
Jefferson	3598	2388	2334	2461
Monroe	2272	2237	2394	2482
Harrison	4251	3018	2678	2511
Jackson	1211	1598	2098	2431
Washington	7748	5880	5796	5755
Twin	2612	2166	2369	2488
Lanier	3512	2581	2592	2598
Israel	1452	1754	2253	2580
Somers	2973	2397	2465	2502
Gratis Twp.	3782	2474	2513	2534
New Paris	1692	1310	1792	2767
Lewisburg	1553	1418	1728	2275
Camden	1507	1525	2449	4729
West Alexandria	1553	1340	1594	2027
Eaton	6020	5834	9081	16791

TABLE 5.1 Results of the Newling Model for Miami Valley Planning Region

MCD NAME	Class	1950 Density	1970 Pop.	1970 Est.	% Error
Allen	1	46.3	1517	1580	4
Wabash	1	44.2	1022	1192	17
Jackson	1	99.1	2978	2308	-23
Patterson	1	43.4	1448	1622	12
Brown	1	64.7	1931	1970	2
Wayne	2	97.7	3736	3471	- 7
Washington	1	34.5	1075	1456	36
Greenville Twp.	2	223.1	15849	9606	-39
Adams	1	77.5	3027	2728	-10
Liberty	1	37.5	1278	1625	27
Neave	1	42.4	1311	1213	- 7
Franklin	1	50.6	1237	1461	18
Harrison	1	42.4	2205	2167	- 1
Butler	1	39.1	1623	1715	6
Twin	2	104.7	3623	3312	- 9
Monroe	1	54.3	1634	1529	- 6
Arcanum	3	1499.5	1993	1933	- 3
Versailles	3	1654.3	2441	2241	- 8
Union City	3	3044.2	1808	1754	- 3
Greenville	3	1876.8	12380	10655	-14
Ansonia	3	2319.3	1044	1007	- 4
Bath	3	643.4	38474	30498	-21
Beaver Creek	3	108.0	26555	12001	-55
Ceasar Creek	1	33.7	1071	1240	16
Cedarville Twp.	1	61.6	3346	2475	-26
Jefferson	1	40.0	1179	1459	24
Miami	2	161.9	5848	3936	-33
New Jasper	1	37.4	1085	1004	- 7
Silver Creek	2	93.0	2907	2789	- 4
Spring Valley	1	46.3	2136	1941	- 4
Sugar Creek	3	59.7	8276	4047	-51
Xenia Twp.	2	350.4	7912	11977	51
Cedarville	3	1763.1	2352	1576	-33
Jamestown	3	2554.3	1790	1512	-16
Yellow Springs	3	1595.0	4624	3610	-22
Bellbrook	3	130.9	1268	918	-28
Fairborn	3	1112.6	32264	10589	-67
Xenia	3	2074.3	25373	15153	-40
Newberry	2	138.4	6598	5675	-14
Washington	2	753.9	22402	9176	-59
Spring Creek	1	59.2	2123	1684	-21
Newton	1	63.3	2947	2788	- 5
Concord	2	469.7	19056	8448	-56
Staunton	2	49.8	3863	2081	-46
Brown	1	51.0	1621	1700	11
Lost Creek	1	40.8	1409	1493	6
Union	2	128.3	9413	5910	-37

TABLE 5.1 (con't) Results of the Newling Model for Miami Valley Planning Region

MCD NAME	Class	1950 Density	1970 Pop.	1970 Est.	% Error
Monroe	2	171.8	9170	4472	-51
Bethel	2	68.7	4284	3260	-24
Elizabeth	1	38.8	1456	1487	2
Pleasant Hill	3	2005.3	1025	1114	9
West Milton	3	1317.0	3696	2732	-26
Piqua	3	3180.3	20741	18690	-10
Troy	3	1818.5	17186	12913	-25
Tipp City	3	1223.7	5090	4366	-14
Bradford	3	2209.8	1240	1487	20
Covington	3	1691.1	2575	2673	4
Butler	3	206.9	19890	12673	-36
Clay	2	139.7	7438	4886	-34
German	2	140.2	7102	4786	-33
Harrison	3	3142.0	34176	30046	-12
Jackson	2	86.5	5823	3781	-35
Jefferson	2	390.9	11790	8040	-32
Madison	3	495.0	29087	21440	-26
Mad River	3	1513.6	43881	22253	-49
Miami	3	666.2	38705	27256	-29
Perry	2	95.7	6020	3943	-34
Randolph	3	251.7	20971	10195	-51
Wayne	3	85.1	27975	4561	-84
Brookville	3	1079.7	20971	10195	-51
Germantown	2	676.4	4088	1262	-69
Trotwood	3	206.1	6997	2084	-70
West Carrolton	3	499.4	10478	4628	-57
Union	3	216.1	3644	716	-80
Centerville	3	94.4	10333	1919	-81
Englewood	3	194.3	7885	1342	-83
Dayton	3	5588.2	243601	230801	- 5
Kettering	3	1198.3	69999	29571	-58
Miamisburg	3	921.6	14797	8901	-40
Oakwood	3	4364.7	10095	9683	- 4
Jefferson	1	67.9	3598	2388	-34
Monroe	1	59.9	2272	2237	- 2
Harrison	1	97.5	4251	3018	-29
Jackson	1	35.2	1211	1598	32
Washington	2	143.5	7748	5880	-24
Twin	1	56.6	2612	2166	-17
Lanier	1	70.7	3512	2581	-27
Israel	1	37.3	1452	1754	21
Somers	1	66.5	2973	2397	-19
Gratis Twp.	1	68.6	3782	2474	-35
New Paris	3	1560.5	1692	1310	-23
Lewisburg	3	2275.1	1553	1418	- 9
Camden	3	921.3	1507	1525	1
West Alexandria	3	2466.2	1553	1340	-14
Eaton	3	1020.6	6020	5834	- 3

total errors in presented is Equation (5.1).

Eq. (5.1) $$CE' = \frac{\text{1970 MCD Count}}{\text{1970 County Count}} \text{*(Total County Error)};$$

If FE > 1970 MCD Count, CE = FE - CE' ;

If FE < 1970 MCD Count, CE = FE + CE'.

where CE' is the corrected estimate,

1970 MCD Count is the census count for the MCD in 1970,

1970 County Count is the census count for the county in 1970,

Total Error is the difference between the sum of the MCD estimates for the county and the 1970 County Count, and

FE is the original estimate of the MCD population.

This method can be extended for any decade for which a reliable county total estimate exists by replacing 1970 MCD Count with the Newling model estimate and 1970 County Count with the county total estimate.

The value of the Newling model lies in its simplicity of execution once the parameters have been determined. It is not a rigorous forecasting method, but it serves the "quick and dirty" purpose well.

FOOTNOTES

[1]Michael R. Greenberg, Kreuckenberg, Donald A., and Mautner, Richard, Long-Range Population Projections for Minor Civil Divisions, Center for Urban Policy Research, Rutgers University, New Brunswick, N. J., 1973.

[2]Greenberg et al, pp. 16-18.

[3]End of direct quotation

[4]Greenberg et al, P. 32.